Smart Technologies

Dep. Automation Control Technologies Engineering

The fourth phase of the two studies

Edition 2023 – 2024

Dr. Ahmed Abdul Reda

Introduction to Fuzzy

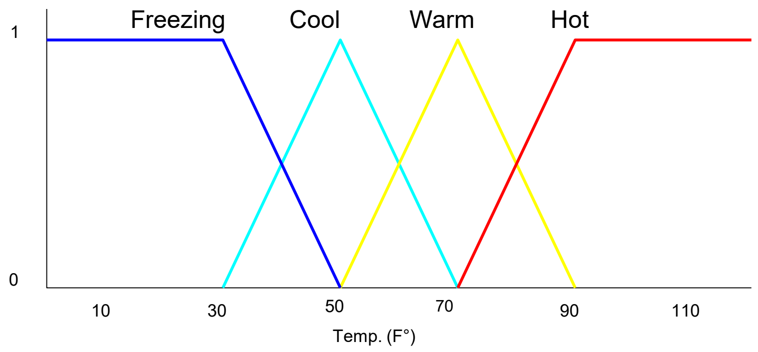
Fuzzy set theory was developed by Lotfi A. Zadeh, professor for computer science at the University of California in Berkeley, to provide a mathematical tool for dealing with the concepts used in natural language (*linguistic variables*). Fuzzy Logic is basically a multivalued logic that allows intermediate values to be defined between conventional evaluations. The story of fuzzy logic started much more earlier . To devise a concise theory of logic, and later mathematics, *Aristotle* posited the so-called ”Laws of Thought”. One of these, the ”Law of the Excluded Middle,” states that every proposition must either be *True* (**T**) or *False* (**F**).

Fuzzy Control

- Fuzzy Control combines the use of fuzzy linguistic variables with fuzzy logic
- Example: Speed Control
- How fast am I going to drive today?
- It depends on the weather.
- Disjunction of Conjunctions

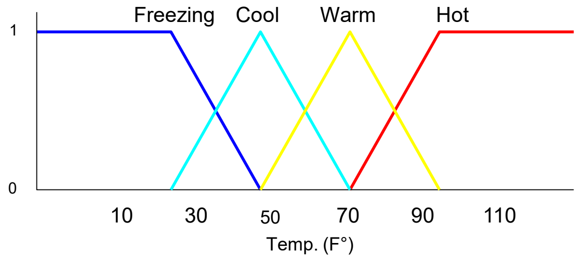
Inputs: Temperature

- Temp: {Freezing, Cool, Warm, Hot}

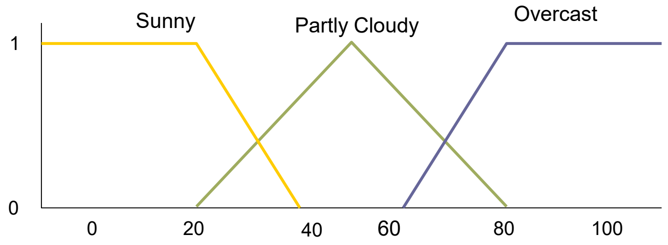


Inputs: Temperature, Cloud Cover

- Temp: {Freezing, Cool, Warm, Hot}

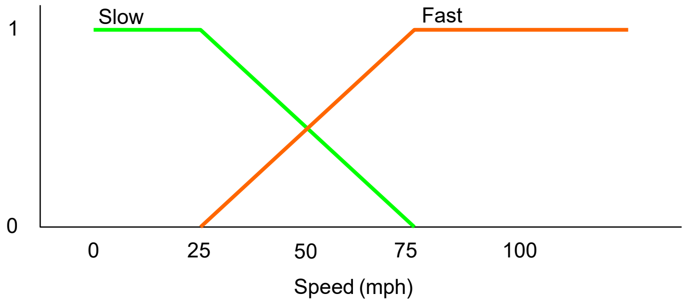


- Cover: {Sunny, Partly, Overcast}



Output: Speed

- Speed: {Slow, Fast}



Rules

- If it's Sunny and Warm, drive Fast

  $Sunny(Cover) \wedge Warm(Temp) \Rightarrow Fast(Speed)$

- If it's Cloudy and Cool, drive Slow

  $Cloudy(Cover) \wedge Cool(Temp) \Rightarrow Slow(Speed)$

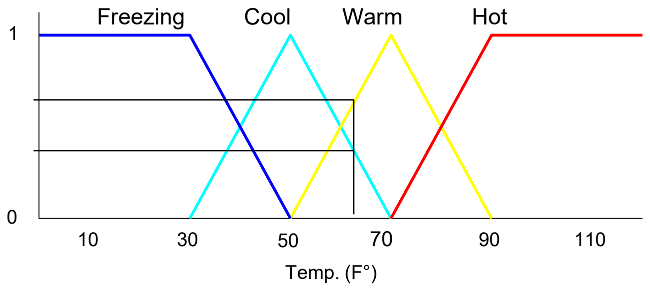
- Driving Speed is the combination of output of these rules...

Example Speed Calculation

- How fast will I go if it is
  - 65 F°
  - 25 % Cloud Cover ?

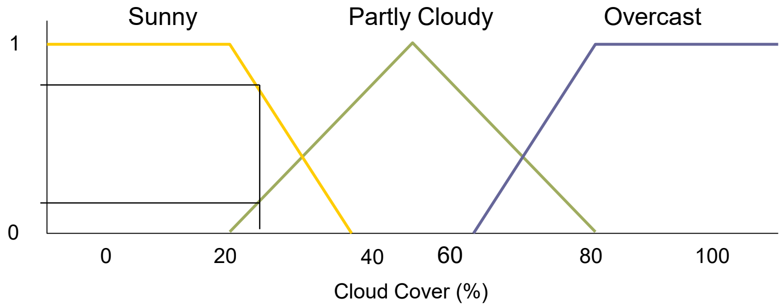
Fuzzification:
Calculate Input Membership Levels

- 65 F° ⇒ Cool = 0.4, Warm= 0.7



Fuzzification:
Calculate Input Membership Levels

- 25% Cover ⇒Sunny = 0.8, Cloudy = 0.2



...Calculating...

- If it's Sunny and Warm, drive Fast

  Sunny(Cover)∧Warm(Temp)⇒Fast(Speed)

  $0.8 \wedge 0.7 = 0.7$

  ⇒ **Fast = 0.7**

- If it's Cloudy and Cool, drive Slow

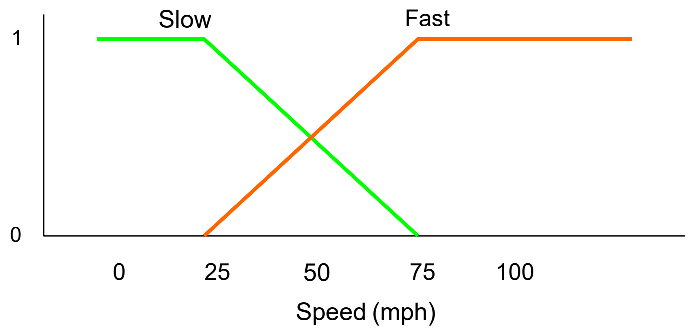
  Cloudy(Cover)∧Cool(Temp)⇒Slow(Speed)

  $0.2 \wedge 0.4 = 0.2$

  ⇒ **Slow = 0.2**

Defuzzification: Constructing the Output

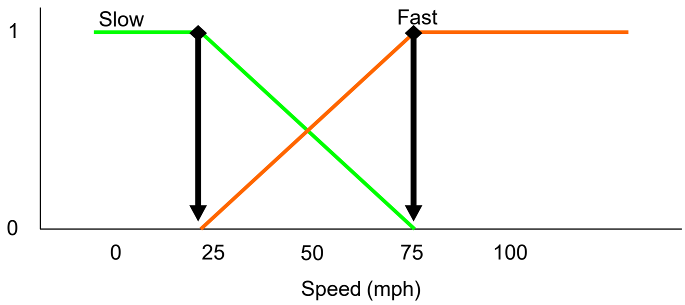
- Speed is 20% Slow and 70% Fast



- Find centroids: Location where membership is 100%

Defuzzification: Constructing the Output

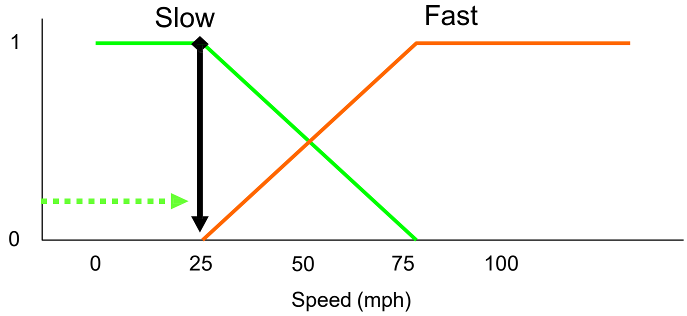
- Speed is 20% Slow and 70% Fast



- Find centroids: Location where membership is 100%

Defuzzification: Constructing the Output

- Speed is 20% Slow and 70% Fast

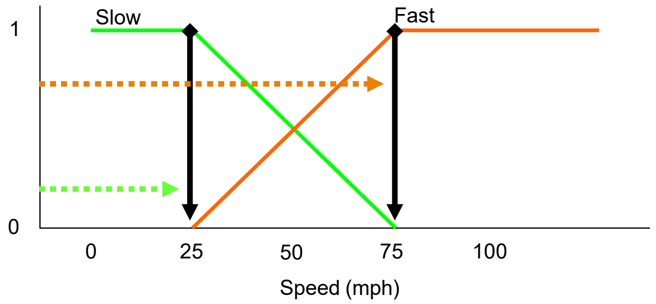


Speed = weighted mean

= (2*25+...

Defuzzification: Constructing the Output

- Speed is 20% Slow and 70% Fast



Speed = weighted mean

= (2*25+7*75)/(9)

= 63.8 mph

Notes: Follow-up Points

- Fuzzy Logic Control allows for the smooth interpolation between variable centroids with relatively few rules
- This does not work with crisp (traditional Boolean) logic
- Provides a natural way to model some types of human expertise in a computer program

Notes: Drawbacks to Fuzzy logic

- Requires tuning of membership functions
- Fuzzy Logic control may not scale well to large or complex problems
- Deals with imprecision, and vagueness, but not uncertainty

Summary

- Fuzzy Logic provides way to calculate with imprecision and vagueness
- Fuzzy Control

THANK YOU